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THE AUSTRALIAN METEOROLOGICAL ASSOCIATION

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CONTENTS

	PAGE
Some common misconceptions about the weather A. T. Brunt	1
Forty Years of British Meteorology A. H. Gordon	4
A Year on Macquarie Island R. Szkup	24
Satellite Meteorology G. Furler	27
The G.A.R.P. Experiment G. Vecchio	30
Sola Salt C. W. Bonython	31
Evaporation C. Purton	33
Weather and Food Production A. Coleman	34
Wind Energy J. O. M. Bockris	35
Recent Drought in the Sahel P. Lamb	38
Weather and Boating B. Harris and L. Broadbridge	42

SOME COMMON MISCONCEPTIONS ABOUT THE WEATHER

Mr. A. T. Brunt

Mr. A. T. Brunt, Regional Director of the Bureau in S.A., spoke at the June 1978 meeting on everything we always thought we knew about the weather (but were afraid to question).

People are very fond of superstition. They spend five times as much time on astrology as they do on astronomy. Throughout history they have produced many sayings about the weather, which have been passed on mostly by word of mouth.

Weather affects everybody, and we all tend to note coincidences, to remember that events or premonitions preceded certain sorts of weather, and to forget that often they did not. For example, whenever I clean my car, it rains. I know it's not true, but I'm still convinced! If two events A and B often occur together, there is no proof, in that fact alone, that A caused B. To seek the truth, always ask whether B might have caused A, or whether both events could be caused by something else.

Here are some sayings, questioned this way.

"Trees cause rain". People have long believed that when trees are cut down, rainfall decreases. The residents of Broken Hill and those of Lebanon have planted trees extensively, but no change in the rainfall of these places has been proved. Trees do, however, reduce runoff. Farmers swear by this saying today, but once they said *"Rain follows the plough"*, which is almost the reverse and has no better statistical basis. Some also say *"It rains on the wooded side of the mountain"*. In fact the opposite of this may be true because, to trees on a mountain, exposure to wind is also important.

"Cyclones come in on high tides". A misinterpretation - cyclones produce their own high tides by low pressure and winds.

"Atomic bombs cause floods". People point to the 1974 floods in Brisbane just after the French atomic tests. These were mere coincidence; there have been many other floods in Brisbane. An atomic bomb is just a "flea-bite" to the atmosphere.

"The equinoxes cause gales". Some have noted higher winds in parts of Europe at these times. In other parts of Europe the windiest season is winter. In Adelaide, March is relatively calm and some Septembers are calm too.

"Weather is affected by the planets". There is no proof of any connection between weather and the planets. In 1982, 9 planets will roughly line up on one side of the sun. This happens every 179 years, and nothing odd has happened on previous occasions, but for 1982 there are predictions of climatic changes in wind direction and temperature, many earthquakes, and a change in the speed of the earth's rotation. It's all eyewash!

There are countless numbers of sayings about plants, animals and the weather. If these sayings worked for farmers, farmers would never be caught by droughts. Here is a sample.

"The amount of fur on animals (or feathers on birds) tells the weather". Wrong. It depends on earlier events, such as changes in the amount of light falling on the eyes, that the animals use as an indicator of season.

"Birds migrate, so they know what weather is coming". This is wrong too. They often get caught in a cold snap. *"Seagulls can tell when storms are coming"* is a variation. Many gulls go inland when no storm follows.

"Swallows tell the weather by flying low or high". This is partly true. The insects on which swallows feed depend in their flight on the state of the air, including its stability. Unfortunately, the various forms of the saying do not agree on whether high or low flight means rain!

The best known ancient saying, *"Red sky morning..."* in its many forms, is basically true. It depends on dust levels in the atmosphere and on regular west-east movement of weather systems, and it sometimes fails. There are many more about cloud types. Sayings about *"Clear air before rain"* have some basis.

In applying sayings from the Northern Hemisphere to Australia, we must remember, of course, to interchange "north" and "south" and to adjust the seasons by six months.

A few years ago, a newspaper from the U.K. noted that plants and animals seemed to be preparing for a bad winter. Winter-nesting birds were ahead of time, snails and rabbits were burrowing deeper, and so on. The story, written in October, concluded that London would have a white Christmas. The outcome was the warmest winter for 100 years, after a very cold autumn.

There was once a plan to change the inland climate of Australia by filling Lake Eyre with sea water. A few years ago, Lake Eyre filled naturally and had little effect on the rain beyond a few kilometres. The Red Sea hasn't done much for the deserts around it, either. The reason is that these bodies of water cannot supply much vapour compared with the oceans. Furthermore, a channel from Port Augusta to Lake Eyre would have to be large to carry enough water to overcome the evaporation rate along its length - it would then be too expensive.

"Lightning never strikes twice..." is frequently disproved. The Empire State Building has been struck hundreds of times. Some trees have been hit many times, too - a tree is not a safe place in a storm.

Cloud seeding is a very political subject. Silver iodide can produce precipitation in a laboratory, and has worked on individual clouds around Hobart. To work, it must be used on a cloud whose top is colder than $-10^{o}C$. Such a cloud will bring showers even without treatment. There have been five big studies in Australia, and they have produced doubtful results at a cost of millions of dollars. One test over the Darling Downs appeared to reduce the rainfall by 13%!

"Hail rockets" are sometimes fired by farmers at approaching storms to dispel hail or turn it into rain. The farmers tend to keep up the practice until one storm produces hail anyway, then to give it up. The fact that rain fell after a rocket was fired does not prove, of course, that hail was avoided.

The moon is often said to affect the weather according to its phase or the angle of its horns, but any effect cannot be large. Whatever the moon's appearance here today, it will appear the same way at all other places (at the same latitude) within 24 hours, so it should affect the weather in the same way all around the globe. In fact, a slight effect has been proved, but not enough for a farmer to notice.

People used to believe that a bumpy plane ride was caused by "air pockets" - little hollow spots in the air. There can be turbulence, downdrafts and other such movements, but no holes.

Statistical studies have done little to prove the water diviner's claims. In a study in NSW, 70% of divined boresites produced water, while 84% of those picked by geologists were successful. It seems that the twitching of bent sticks is not related to the presence of water underground.

"Our weather comes from Perth". This saying is often believed, but often disproved. Even when pressure systems move eastwards, and they frequently do not, the weather does not follow them unchanged. The vertical movement of air is more important than long distance horizontal movements.

Many people claim that they can produce long-range forecasts. Such an ability would be worth millions of dollars a year. Often such people look for regular events (or "cycles") in past records and assume that these events will come regularly in the future. Many cycles and lengths of cycle have been "discovered" for weather and for sunspots, but the only cycle that works is the 12 month cycle - for the seasons. Long-range forecasts of the kind discussed in the papers have not done very well.

Of course, if a forecaster is pressed for a long-range forecast for a certain moment (such as a wedding) he can safely say "fine". He will be right 95% of the time!

Finally, those who claim that the weather is not what it used to be are right. There have been slight changes, but they are far too small for the man in the street to notice.

40 YEARS OF BRITISH METEOROLOGY

A.H. Gordon

Text of a talk given at the meeting of December 1977. The original was illustrated with photographic slides.

When the topic of my talk this evening was first suggested, it made me think of the titles of those old Victorian Music Hall Melodramas - you know the kind of thing I mean, where the villain was hissed and the hero cheered loudly whenever each appeared on stage.

Like

"Just in Time"

or

"How truth and virtue triumphed over evil".

This was because the aesthetic appeal of this quite incredible Meteorological Bureau building led me to the title

"The British Meteorological Service"

or

"Horrible Buildings I have worked in".

Alternatively,

"40 years of British meteorology"

or

"Horrendous forecasts I have made"

Now I do not intend to present a serious history of four decades of British meteorology. This might become a little tedious after the first six months - with still thirty nine years to go. I shall instead, during the first part of the account, occasionally dwell for a moment or two on one or two utterly trivial incidents arising from my own exposure to meteorology as a forecaster of weather. During the slightly latter portion of this talk I will attempt to survey the work of the U.K. Meteorological Office as it is today.

The present Headquarters Buildings of the Meteorological Office in the U.K. is at Bracknell in the County of Berkshire, about 35 miles west southwest of London. In describing its pinpoint location to overseas visitors, particularly those from Australia, I mention that it is just 4 miles west of Royal Ascot Race Course. Somewhat surprisingly this piece of very useful information does not seem to define its location as closely as I would have expected, and I usually have to go on and say that it is 12½ miles southwest of Windsor Castle, or 3 miles north of the Royal Military Academy at Sandhurst, or possibly even that it is 5½ miles northeast of Broadmoor, the well known mental hospital for the criminally insane.

If then as a result of all these very precise directions a visitor should find and enter the portals of this institution one will see an oaken inscribed panel in the foyer. This lists the names of all the Directors and Directors General of the Meteorological Office from its foundation to the present day.

There is no better starting point, than to pause over the name of Sir Napier Shaw, often called the father of present day meteorology.

During the course of an astonishing career, and one which has probably not been surpassed since by any British meteorologist, he published a number of classic textbooks, including the vast 4 volumes of his Manual of Meteorology. He was a dedicated synoptic man, devoted to the weather, a breed rapidly becoming extinct, the species having been largely mutated into fluid dynamicists, numerical modelers and dishpan operators, who seldom look out of the window to see the sky. Napier Shaw was an innovator who looked to the future. He was one of the first to evaluate the trajectories of the large scale air currents and relate them to the prevailing weather in terms of the modern concepts of convergence and divergence. He also made what is believed to be one of the first time lapse films of motion in meteorology. His first film was made in 1911 of high cirrus and altocumulus cloud speeded up ahead of an advancing depression. He later also made an animated film to show how meteorological processes work.

I never met Napier Shaw, who was 82 when I joined the Office. He actually lived to 91. However, I did meet Shaw's younger colleague, R.G.K. Lempfert, the co-author with Shaw of a book "The Life History of Surface Air Currents". Lempfert interviewed me for my appointment in 1936 at which time he was Director of Personnel.

Napier Shaw was followed by Sir George Simpson as Director. Simpson had an international reputation in atmospheric electricity. As a young scientist he accompanied Scott on his Antarctic Expedition. He was married in Sydney so had a strong association with Australia.

The Meteorological Office always dominated the meteorological scene in Great Britain. Only one university, Imperial College at the University of London had a department of meteorology, and this state of affairs continued until 1965 when Professor Reggie Sutcliffe opened up a small school of meteorology at the University of Reading, not far from Bracknell. The Chair of Meteorology at Imperial College was held for many years by David, latterly Sir David Brunt, one of the foremost scientists of his day. The universities and the Royal Meteorological Society played important, but somewhat lesser roles in the overall development of the subject, but both bodies have contributed in their own way a great deal to extend meteorological interest to student and layman, and to other organizations in the outside world.

In the middle 1930s meteorology was undergoing some revolutionary thinking in terms of the Norwegian School of Air Mass Analysis and frontal theory. The ideas had been slow in adoption by the British and United States Services. However, visits by Professors from the Scandinavian School, especially Petterssen, Bjerknes, Bergeron etc. helped the new ideas take root.

As far as data was concerned the United States was far ahead of the U.K., but this was more due to the initiative of the private airline companies than to the government service there. The airlines established their own observing and teleprinter communication network in order to assure a satisfactory forecast service for their flights. It was almost as commonplace to fly in the U.S. in 1936 as today but passenger flights were very rare indeed in England where all journeys were made by train, even to the continent of Europe. The airlines in America employed their own meteorologists, a career which offered jobs even in the dark days of depression unemployment.

An excellent network of upper air observations also existed in the U.S.A. in the 1930s in addition to the gathering of surface data. These observations were used to construct aerological diagram ascents to determine stability and instability in the same manner as today. Upper air synoptic charts plotted on constant level or constant pressure surfaces were not drawn as far as I can remember, at that time.

In the U.K., however, the radio sonde was not in operational use, as in the U.S.A. in 1936 when I joined. Upper air soundings were obtained by aeroplane ascents from two Air Force airfields twice daily, once at weekends. All data received at outstations and forecasting offices was by radio in morse code. The original reports were first passed to London by fixed time telephone call, or by telegram in the case of outlying coastal stations such as lighthouses and coastguard stations. Teleprinters were not used until about 1938 when the big war rearmament programme was underway.

It was while understudying senior forecasters at the Air Ministry Headquarters that I first became aware of a horrendous forecast. I was not myself involved but the person I was understudying prepared the advisory forecast for the whole U.K. for the case in question. He was exonerated from any blame but a less fortunate forecaster at the airfield near Belfast in Northern Ireland ran into serious trouble which hindered any prospects he might later have had for advancement.

A Royal Air Force Squadron was based at a station in Yorkshire on the eastern side of the Pennine range of hills. This squadron was on temporary duty in Northern Ireland. On a Friday morning in December 1936 they asked for a forecast for a flight back to their home base, so that they could be home for the weekend. An old occluded front lay along the Pennines and the forecast, which followed the London advisory closely, gave low cloud and rain or sleet, very poor visibility, especially near the hills and so forth. In spite of the very bad weather conditions predicted, the Squadron Commander ordered take-off. After all weekends were important then, too.

What happened?

Of the dozen planes which took off half crashed into the Pennines with considerable loss of life. A quarter landed at various other airfields scattered around the country and the final quarter managed to get through safely.

The rumpus which followed was frightening for a new recruit forecaster to see. All the assistant directors strode into the forecast room on Monday morning. Questions were asked in the House of Commons while the Air Force top brass demanded some forecaster's blood. Very close scrutiny of all

the information supplied brought out the fact that mention of ice accretion in cloud had been omitted from the pilot's briefing documents, although this danger had been included in the advisory issued from London. It was enough to point a finger at the airfield forecaster who had briefed the pilots. When any accident occurred it was nearly always the weather which first got the blame and the forecaster in particular. This and other examples show the great responsibility and stress taken on by forecasters in those days, responsibility for life and limb and aeroplanes.

Within the year I had a personal taste of the same kind of thing as that just described. Fortunately, I was covered, probably more by good luck than good management. It was October 1937 when I was stationed near Oxford on an R.A.F. airfield that I had a phone call and was asked to prepare a forecast for a flight from there to an airfield in northwest Wales, on the seacoast. The request specified that if the weather was O.K. the route to be taken would be as the crow flies across the Welsh mountains, but if poor conditions were likely then the squadron would fly over flat country to Liverpool, and from there follow the coastline below cloud level to their destination. As a warm front was moving in across the Irish sea I gave my forecast for the latter, safer and longer route. Conditions were very good to Liverpool but a deterioration would take place along the Welsh coast to the west, with cloud on all hills, poor visibility etc. No icing was involved as it was too early in the autumn and the air mass was warm. The forecast was just routine, and I promptly forgot about it. There seemed no worries, if the squadron skirted the coastline, as advised.

That evening, in Oxford, I noticed headlines in the local evening paper.

R.A.F. Squadron Disaster
Planes crash in Welsh mountains

At first I didn't give them much thought. Then suddenly - I realized - this was my forecast.

It was almost a carbon copy of what had happened in the previous case. The Air Force this time had stationed their own untrained observer at the destination airfield. He had reported fine early morning conditions. The Squadron Commander had preferred this report to the official forecast and they had taken off on the direct route across the mountains of Wales. In the meantime the warm front had moved in, covering the mountains and enveloping the coastal destination in thick drizzle with low cloud and poor visibility.

I felt fortunate to have escaped the incident unscathed.

It was while at this station that I met an older very talkative forecaster who said that statistics showed that forecasters either went crazy from the strain, or retained their sanity and lived to be over 90 years old. He quoted several examples, of which there have been more since.

In the spring of 1938 I was married and we volunteered for service in Egypt. The following September I was posted to Gibraltar.

It is here that I may refer to my phrase of "horrible buildings I have worked in".

It was situated on the southern edge of the Rock at a site called Windmill Hill Flats.

Try, if you can, to imagine a lightly constructed observation hut, built on a cliff precipice and supported by rusty struts. When war broke out in 1939 it was faced by Franco guns from across the Bay in Algeciras. There was a Dines pressure tube anemometer constructed on the roof of the hut. The only example I know of a station where the wind direction vane acted as a cup anemometer. The eddies from the cliff made the vane rotate continuously.

In spite of all this the office was a very pleasant one in the prewar months before September 1939. There was a fantastic view across the Straits to the Moroccan mountains and to the Sierra Nevada snow-capped peaks in Spain. The winter weather was beautiful, the latitude being similar to that here in Adelaide.

At about this time Sir George Simpson retired and was replaced by Nelson Johnson, who was later knighted. Sir Nelson captained the Met. Service through the darkest war years and directed the enormous expansion and organization which the war necessitated. He lived in his office night and day through all the bombing and rockets, occasionally taking a weekend off with his family in Cornwall. It was said that any staff who might be reporting for duty at an early hour in the morning, would find Sir Nelson cooking sausages for breakfast in the corridor, outside his office. He later became President of the International Meteorological Organization and saw the transfer to and the birth of the present day World Meteorological Organization. The WMO was a big step forward for meteorology as it represented an official Governmental Body with United Nations status, whereas the old I.M.O. was really only an unofficial body composed of the Directors of the different Services throughout the world.

Unfortunately, the terrible responsibilities of the wartime years and the nerve wracking tensions in London took their toll. Sir Nelson fell ill and met a very tragic end.

In Gibraltar the first few months of the so-called Phoney war passed by peacefully enough. But things looked black in June 1940 after Italy came into the war, and France had collapsed. Wives were ordered to be evacuated back to U.K. and our vulnerable little office was to be transferred underground. We all thought we would meet a horrible death defending the Rock. And this might well have been the case if OPERATION FELIX had occurred, the code name given to Hitler's plan to seize Gibraltar. Only the obstinacy of General Franco to Hitler's demands saved what could have been a dreadful last ditch stand. Things looked very black indeed.

Some of you may have seen placards in people's offices which read CHEER UP. IT MAY NEVER HAPPEN. No more fitting truth happened than in my subsequent experience there.

I was climbing up the stairs to our apartment with my wife. The top flat was occupied by another forecaster in the office. As I mounted the steps in the depths of despair a voice called out "You must be the luckiest chap alive".

A signal had come from the Air Ministry posting me to the West Indies. There were many adventures before we got there which I will not go into, travelling through submarine infested waters. I had been briefed in London to set up a forecasting service in Barbados for the ARMY, AIR FORCE

and NAVY. On arrival I found no army, except for a local volunteer force composed of one officer and half a dozen men, no Air Force and no Navy. There was one rather derelict airfield but no planes used it. The office we set up was not horrible although a little unusual. It consisted of a lonely and deserted officers' mess of the local volunteer corps. The only officer never used it. It was in a patch of jungle and full of Punch magazines going back to the 1880s.

My posting, which was supposed to have been for three years only, lasted for three months. I was transferred to BERMUDA. The Air Ministry had finally discovered the lack of an army, Air Force or Naval unit in Barbados.

Before the war there were three Meteorological Services. The Met. Office was the largest and most comprehensive. The Navy always liked to be independent of everyone else so they set up their own in 1937. There was also a Colonial Met. Service.

We in the Met. Office regarded the Naval Service, and particularly the Colonial Service, with some suspicion. They seemed to be a different breed, spoke with different accents and rarely published any scientific work in the journals. At least that was the impression gained, rightly or wrongly. During the war the Met. Office took over the Colonial Service Administration. However, they left the old guard in charge at overseas stations and augmented the Service with Met. Office staff. This mixture did not always work too well as the Colonial staff had developed Colonial ways which were new to the younger professional scientists. Bermuda was one of these - formerly a pleasant easy going little office - which was now forced to set up a complex organization to supply forecasts for the delivery of Catalina flying boats to Scotland.

Here was another somewhat horrible office. It was set in an underground fort without windows and about 200 years old. I think the offices had been used for dungeon cells in the pirate days. They were cold and damp. The only advantage was on one occasion when a tropical hurricane passed over and then we were all well protected from the elements.

The day after Pearl Harbour I received a signal to return to U.K. A week later I was aboard one of the CATS as a crew member and after 24 hours landed in thick low cloud in the midst of a bunch of barrage balloons on the Clyde River. My next posting was to the international airport at Prestwick in Scotland. This was the prototype of all the large international airports to follow and a complex organization had been built up to take care of trans-Atlantic flights for passengers and for the delivery of the B 17s or Flying Fortresses as they were called from the United States, bound for their bases in Eastern England.

It was about this time that the first upper air charts began to come through on the teleprinters, originating from Washington broadcasts. They were for 10,000 and 20,000 feet levels. It was not until after the war that international agreement was reached to plot upper air charts on the 500 millibar and other constant pressure surfaces.

The building we occupied at Prestwick was a large country house and I remember in particular the huge fireplace in the forecast room where forecasters were wont to doze in front of the flames between forecasts on cold Scottish nights.

I was concerned with two forecasts of some memorable note in my mind there. On one occasion I was sent in a chauffeured limousine to a small flying boat station about a hundred miles away. I was told to use the facilities of the little office there to prepare a forecast to New York via Gander in Newfoundland. At that time all flights to the American continent had to land at Gander, or be diverted to Goose Bay in Labrador. GANDER or GOOSE, which was it to be, was the eternal question? Gander was about the world's worst airport from the point of view of the weather. At least three quarters of the time it was affected by thick sea fog, low stratus cloud at 150 feet or less above the ground, heavy rain or drizzle, or failing any of that, blizzards with visibility down to near zero. The main reason for all these awful conditions is the presence of a very cold ocean current off the coast. Any of the conditions mentioned could occur within minutes of a change of the wind to an easterly point. It was a veritable forecaster's nightmare.

The fact that any Westbound aircraft nearing Gander was getting near the end of its fuel range did not help matters. The diversion to GOOSE BAY had to be made in good time, about half way across the Atlantic at the latest.

Well, on this particular occasion I arrived at the small forecasting office, only to encounter the regular forecaster there walking off. He was in a bit of a huff because he had not been left to do the job himself. So I was left to my own resources with one assistant. The forecast this time not only involved landing problems at Gander, but takeoff problems. It was always necessary for the takeoff airfield, or flying boat base to remain open for several hours after takeoff in case of an emergency return landing. There was now a prospect of low sea fog drifting up the loch from the open sea, in a moist air mass. I had to brief a well known pilot of the time, a Captain Kelly Rogers, a legend in British Airways flying boat history. His parting words to me were:

> "Well if anything happens and we don't get there - you'll hear about it".

The next morning there was an announcement over the radio that Winston Churchill had landed in New York enroute to Washington for a meeting with Franklin D. Roosevelt.

On another occasion I came on night duty at Prestwick and was told by the flying control officer that there were 150 B17s in the air on the way from Gander, and due to land at 6am. They would pass their point of no return in a couple of hours and was everything OK for landing? I was very unhappy with the latest chart for 9pm as it showed a change of wind to southwest and a consequent danger of low stratus drifting in from the sea. This was the only direction to fear as Prestwick was well protected by hills from low cloud coming from other directions. The planes were due before dawn - it was winter - and all the pilots were young trainees, little more than teenagers on their first long flight. They had certainly never crossed the Atlantic before. Anyhow, after a somewhat agonizing discussion the flying control officer agreed that the 150 should be sent back to base at Gander, which was fortunately clear. About 3am low stratus cloud started to drift in across the airfield. At dawn it was overcast - ten tenths at a base of about 300 feet, well below the safety condition laid down. It should be mentioned that the island of ARRAN with

mountains up to 2000 feet was only 20 miles to the west on the approach flight path and already two Liberator planes full of passengers had crashed into it, one taking off and one attempting to land in bad weather. As the gloomy Scottish daylight crept in we heard one plane circling in the darkness above the cloud somewhere. It was in fact another legendary British Airways pilot, a Captain Messenger, flying in his Liberator. Messenger never worried about weather and flew in conditions shunned by other pilots, but he later admitted that that particular landing had been a difficult one with cloud almost on the deck and in the dark blackout.

So I like to think, rightly or wrongly that a lifetime's salary as a meteorologist was well earned in that one night as anything might have happened had 150 inexperienced American pilots tried to land in the murky dawn weather that morning.

From Prestwick I occupied a different kind of building. This was in ICELAND in a NISSEN hut. Large huts for the offices - small ones to sleep in. Sometimes the snow was so deep it was difficult to open the door. ICELAND was occupied by the British without invitation very largely for meteorological reasons. It was most important for the U.K. and the Allies to safeguard reports from the country which was the centre of much weather activity. Stations were set up at R.A.F. airfields but the Icelanders continued to make their own routine reports. Three British airmen in the Met. contingent were posted to the main Icelandic Met. Office in the centre of the town of Reykjavik to collect, code, and transmit the routine observations to the Air Force H.Q. Office where they were transmitted point to point to Prestwick and thence distributed on the internal landline teleprinter system.

Incidentally the person I replaced in taking over the Allied Met. Service in Iceland in May 1943 was David Arthur Davies, the incumbent Secretary General of the W.M.O. since 1955. This in itself was a useful experience as I gained an insight into the tremendous organizational genius of D.A. Davies.

It was while stationed in Iceland that the most horrendous forecast of all was made - but this time I was not directly involved.

I refer to the big D DAY Forecast - codename "OPERATION OVERLORD" - well documented in J.M. Stagg's book of the same name.

I would like to give a little background to this momentous forecast for which Jimmy Stagg had been commissioned as a Group Captain in the R.A.F. Meteorological Branch and was almost wholly responsible in his capacity as Meteorological Adviser to General Eisenhower.

Jimmy Stagg was a tall, thin Scotsman, puritan and self disciplined, hard working, critical and with strong views. I had met him once or twice briefly before and he was later to become my boss at Air Ministry. I personally liked and admired him enormously , more than anyone else in the Service but this was not a universal view. As a whole he was never very popular with the staff and was in later life to be disliked by many who did not care for his authoritarian schoolmaster manner.

During the events leading up to D DAY, Jimmy Stagg was the liaison officer between the various meteorological centres. His job was to seek an agreed solution to the forecast from all the participating

organizations involved.

Nearly all the American counterparts were fellow students of mine at Cal Tech in 1936. The class was in fact mainly military, there being only 5 civilians altogether. Both Irving P. Krick and Sverre Petterssen were professors of meteorology teaching our course. All the participants had vastly different personalities and approaches to forecasting and it was because of the conflicts which arose on these grounds that made Jimmy Stagg's task such a difficult one.

Irving Krick was a promoter of meteorology. A business type of man who had been an excellent practical weather forecaster and analyst of synoptic charts. Not highly academic himself he was a staunch supporter of all the latest methods and technology. Later in life he fell foul of the meteorological establishment by indulging in what his colleagues judged to be unethical practices-like making detailed forecasts by computer a year ahead to the day and charging for his services.

Petterssen was both academic and practical in his approach and also a very good analyst and forecaster - often at cross purposes with Krick. Another was F.K.M. DOUGLAS, an amazing forecaster who had served in the first World War in the Flying Corps and been gassed.

Douglas, although brilliant in his way, was not an academic. He relied on an almost prodigious memory of every synoptic event that had happened during the past twenty years or more. Like a computer he could recall almost every synoptic situation from the past and how it had developed. He had a very rambling approach, rather uncoordinated and this presentation did not impress the Americans with their highly developed systems and technology. Of course, meteorology being what it is, he was in fact a much better guide to the awesome decisions that had to be made than the trendies of the day. The same holds true to some extent at the present time.

Although the secret of D DAY was well kept there were signs for us in ICELAND that something was afoot. Early in May 1944 all leave and postings movements were cancelled. Late in May rumours reached us that all incoming and outgoing mail had been suspended. Obviously something big was about to happen.

Although I was not directly involved I like to think I was in an indirect way, as I was responsible for the efficient transmission of the Icelandic observations. These observations were extremely important. (Weather maps leading up to D Day can be found in Stagg's book.)

Just a few days ago I had a letter from Douglas. He is now in his middle eighties and he writes a most lucid letter about meteorology in general and the D Day forecast in particular.

I quote some extracts:

> "A point that I could enlarge on was the element of luck. The onshore wind was above the permissible limit previously laid down by the Admiralty, and by all accounts must have been near the actual limit above which the landings would have been impossible.

> The depression which moved quickly northeast to North Scotland became exceptionally deep for June, and this hastened the advance of a cold front needed to clear the thick low cloud of 5th June, the original D Day. Everyone thought it would go on moving NE, even if more slowly, but it suddenly became stationary and moved slowly SE while filling rapidly. This held up the next front and prolonged the tolerable interval."

After the occupation of Germany and Austria by the Allies at the end of the war the Met. Office took on the important role of participating with them in setting up an Allied Weather Service and in later supervising the establishment of reconstituted Meteorological Services. Jimmy Stagg had been appointed to Berlin long before the war was actually over. Between September 1944 and March 1945 he prepared for this job in London while at the same time assuming the administration of the Meteorological Branch concerned with Coastal Command, at the Air Ministry. I happened to be his Deputy at the time and took over from him when he left for Berlin. Subsequently, I was appointed to the similar, but smaller version of the same job in Vienna. It was in fact a missed opportunity for me to turn down an offer to be Stagg's Deputy in Berlin. I had just returned from 18 months overseas and wished to remain at home for awhile. A year later Stagg was promoted to the number two spot in the Office, the Deputy Director, a post which he held for 16 years until his retirement.

I must at this point make one last mention of horrible buildings. It was in Vienna and could hardly be called that because it was in the Schonbrunn Palace, the residence in former times of the Hapsburg Emperors. The City of Vienna was divided up between the Americans, British, Russians and French and the British got the Palace in their sector. The Army took over the best part of the Palace leaving the Air Force with the stables and servants quarters for their officers. However, the Air Officer Commanding succeeded in installing himself in a vast room which must have been used for the audience of foreign dignitaries in olden Viennese times.

After the war was over the Met. Office took on a new shape. It was split into two halves, Research and Services. Prior to and during the war, research was a luxury which could not be afforded within what was primarily an operational service to meet the needs of the Royal Air Force and a limited number of public enquiries and climatological records.

Reorganizations of the structure have been a continuous feature of Met. Office life. I am sure there has been an average of at least one reorganization per year, starting with the outbreak of war, when of course it was clearly necessary. However, the continual changes were welcomed in some respects and disliked in others. If the reorganization meant new posts and promotions, they were looked forward to with great excitement. However, in some cases staff found their jobs had been split in two, like an amoeba, and responsibilities had in fact been downgraded, together with additional pipelines and channels to negotiate in the hierarchy. The new half might be filled with a new promotion whereas the old half continued as before in his old grade.

The 1976-77 budget was about A$45 million. Of this it was expected that A$13 million would be recovered for services rendered on repayment basis.

I will go through the Branches briefly starting with the Services and finishing with the Research side.

Personnel (Met. O. 10)

The most feared Branch. Responsible for postings at home and overseas. Also promotions and all other personal matters. Although nominally under an Assistant Director the operational work was conducted for many years by two elderly ladies who were feared by all, including the Directorate themselves.

Nowadays postings are done more humanely.

Public Services (Met. O. 7)

Each year the Annual Report of the Office highlights a special topic, one for the Services and one for Research. In 1976 the Services topic was the Offshore Oil Industry. This is a fairly new requirement in which private consulting meteorological organizations have been involved. A highly specialized service is given in a number of aspects of the industry. An example is Climatological advice for the North Sea Region, to give extreme value probabilities of wind and waves for engineering design of the rigs as well as for continuous forecasts of wind, weather and waves for periods of one to four days ahead. Perhaps the largest single operation for which weather forecasts are decisive is the tow-out of the platform to an oil field after construction. It requires quiet sea conditions to be sustained for several days during installation. In addition to these and other marine and shipping forecasts Public Services as the name implies is responsible for services to the public and private sectors of the nation, excluding aviation, that is, to the media, television, radio, the press, including the automatic telephone service. Much of this work is done by "Weather Shops" in London and the major provincial cities. Other services are to British Gas Corporation, the Central Electricity Generating Board, British Rail and London Transport. Advice also ranged from forecasts for pigeon racing to notifications to farmers of dry spells during the summer. The latter service did not prove very popular in 1976, understandable perhaps in view of the prolonged drought during the 1976 summer.

Defence Services (Met. O. 6)

Whereas today only one Branch out of 22 is devoted to Defence, in pre-war days about three quarters of the total potential was devoted to this one aim, so that one can get an idea of the enormous expansion of the Department. The Met. Office still comes under the Ministry of Defence, possibly for financial reasons as there may be more money available from that Ministry. Previously it came under the Air Ministry. Most of the work of this branch is concerned with the administration of outstations at home and overseas which are located at R.A.F. stations. Very little is concerned with the Army. In fact the Army has never been an important customer, its main requirements being the supply of winds for ballistic purposes. The Royal Navy, of course, have their own private meteorological service.

Central Forecasting Office (Met. O. 2)

Met. O. 2 has retained its own number since time immemorial. It consists of the Central Forecasting Office and is sometimes referred to as C.F.O. When I joined the Office in 1936 MO 2 was located in Adastral House in Kingsway, later moving up the street. After war broke out the Branch was relocated at Dunstable, a market town about 50 miles north of London. It remained there until 1961 when it moved to the top floor of the new Headquarters Buildings at Bracknell, Berkshire.

Bracknell is a Regional Meteorological Centre within the framework of the WMO World Weather Watch. The three Meteorological World Centres are Washington, Moscow and Melbourne. The main function of the Bracknell Centre is to provide the basic and fundamental forecast advisory material for the whole country as well as for the Region for which it is responsible. To do this it has one of the largest computers in the world which, using advanced and sophisticated mathematical and numerical models, issues in grid point and map form analyses and predictions for the surface and all the standard levels of the atmosphere. 10 levels are used in the present primitive equation model.

The forecasters on duty still draw up their own charts with pencil and rubber but when they make forecasts they draw heavily on the computer output for guidance. The Central Forecast Office is a hive of activity, working 24 hours a day, 7 days a week. Some forecasters analyse surface maps of the Atlantic Ocean covering an area from the Pacific to Siberia and from the Arctic to North Africa. Others draw charts of Europe alone, others charts of just the United Kingdom alone - big maps drawn every hour ad infinitum. Still others analyse upper air charts, aerological diagrams, while yet others try their hand at extended forecasts for up to 3 days ahead, using basically synoptic methods. Then there is a team of ancillary workers.

Systems Development (Met. O. 22)

This is a new branch which has been formed and the name coined long since I left the Service. The duties of the branch are defined as:

1. The build up and usage of all the past and continual input of data in digital machinable forms.
2. The investigation and application where needed of new computer systems.

These duties in practicable form cover among other things the transfer of 6½ million punched cards of marine data onto magnetic tape. Also the digitization of satellite pictures, both visible and infra-red and library automation. In fact the entire range of converting all past and present data onto magnetic tape for input to the computer and subsequent output on visual display units, line plotters and printers.

The Branch states

> "in the context of numerical modelling in dynamical meteorology where computer speeds of at least 50 million arithmetic operations per second are likely to be required by the end of the present decade....."

It is my own personal point of view that there is a limit to the speed and vastness of the data beyond which no further improvement in

forecasting will result. To go to the extreme, suppose one had an infinitely fast computer processing an infinite amount of data, would the forecasts become an exact replica of what the real world might or might not do, or does stochasticism take over long before this state of affairs is reached?

Data Processing (Met. O. 12)

The branch is responsible for the day to day operation of the main computer called COSMOS. This includes controlling the steady flow of data from the automatic telecommunications complex to the computer, and on to its production in operational and usable form. The branch ensures that time on the computer is fairly shared between the rest of the office and is not overloaded.

The main use of the computer is of course to provide numerical output in grid point form from which line drawing machines produce synoptic maps of various parameters for use in the Central Forecast Office and transmission to outstations and oversea.

Telecommunications (Met. O. 5)

This is such a vast organization - the brain of operational synoptic meteorology. The branch is responsible for the day to day working of the automated teleprinter and facsimile network and for the reception, exchange and transmission of all data in accordance with international agreements.

Operational Instrumentation (Met. O. 16)

Operational instrumentation is responsible for meeting the changing needs of the Met. Office for instruments and data-acquisition systems. It carries out the design and development of the needed equipment. In recent years most attention has been devoted to automatic weather stations. One of the new instruments now being developed is a laser beam cloud base recorder.

Recent new instruments put into operation are digital anemograph logging equipment (DALE), automatic climatological recording equipment (ACRE).

Agriculture and Hydrometeorology (Met. O. 18)

The collection, quality control and preservation of rainfall observations from some 6800 stations and evaporation from some 60 stations in the U.K. is one of the major tasks of this branch.

The precision encoding and pattern recognition equipment has been used to digitize traces from 1¼ million daily autographic rainfall charts.

One section of the branch has suites of computer programmes for the tabulation of rainfall amounts in specified durations (one minute to 25 days) which will be equalled or exceeded for various return periods, say twice a year, to once in every thousand years. Such information is necessary for the construction of bridges, buildings and other public works in order to guard against flooding.

All this has come a long way since the days of the British Rainfall Organization which existed for many years in the past, and which was probably one of the most thorough rain data collecting organizations in the world.

The agricultural half of the branch supplies a service to farmers and agricultural interests in all possible ways, ranging from apple scab and potato blight to the design of pig houses and mortality of new born lambs.

Climatological Services (Met. O. 3)

There are some 630 observing stations which make climatological returns of which 80% are voluntary. This branch deals with all enquiries about the climatology of the U.K. and surrounding oceans. Special studies to determine the maximum current which can be carried by exposed cables of the Electricity grid and of motorway extensions in the light of prevailing conditions have been performed.

Of course modern climatology is not just concerned with mean or average values but depends on frequency distributions and correlations which require special computer programme suites.

Observational Requirements and Practices (Met. O. 1)

The branch is responsible for observation networks and for the quantity and quality of all observations over land, sea and in the upper air. It administers geophysical observatories at Kew, Lerwick and Eskdalemuir in Scotland.

The U.K. synoptic network consists of 260 stations of which 75 make hourly reports and 47 make 3 hourly reports throughout the 24 hours.

There are 8 upper air radiosonde stations in the U.K., 4 overseas and one ocean weather ship station.

This branch contains the Marine Division under a Marine Superintendent. The Marine Branch from time immemorial was always called MO 1. The recent reorganization has therefore downgraded it from a Branch to a Division and it has lost its original entity. Some of the old Marine Superintendents, men from the Royal Navy or Merchant Navy would never have allowed this to happen and would turn in their graves if they knew. The Division is responsible for the administration of the ocean weather ships. Only one station at 57°N 20°W is now operated by the U.K. alone. The Marine Division maintains a staff of port meteorological officers who liaise with ships' captains to recruit ships to form the voluntary observing scheme for ships. The Met. Office supply the instruments for this purpose.

International (Met. O. 17)

A small administrative Branch that is the channel between the Director General and the WMO, ICAO and NATO Organizations. Preparations for Congress and the Executive Committee meetings are made.

In 1975 the present Director General lost his seat on the Executive Committee of the WMO. This is the first time that this has happened to U.K. in over a hundred years of international meteorology. It was

mainly due to wheeling and dealing and politics within the WMO at the last Congress. The Director of the Australian Commonwealth Service retained his seat, which he has held now for a number of years.

We now come to the research branches, on the other side of the house as we say.

Geophysical Fluid Dynamics (Met. O. 21)

We might term this the dishpan branch - probably the most expensive dishpans in the world.

One of the ways in which atmospheric behaviour has been studied since the late 1940s is to simulate the earth in model form in a rotating vessel - the so-called dishpan. The cylindrical vessel is filled with water to a depth of say 5 or 10 cms. The rim of the vessel is heated by electric elements to represent the equator, while the centre of the vessel is cooled with ice to represent the pole. Using what is called scale analysis a rate of rotation is set up to simulate the rotation of the earth, bearing in mind the scale of the system relative to the earth. Typical Rossby numbers are allowed to occur, that is the ratio of the velocity of the fluid to that of the rotating surface.

With large values of the Rossby number, that is with low rotation rates, the circulation develops into a Hadley cell or meridional type of motion, whereas with small values of R or high rotation rates the flow becomes geostrophic and develops into a wave pattern similar to the Rossby waves observed on upper air synoptic charts. The value of U is the geostrophic value caused by the meridional temperature gradient between the "equator" and the "pole" of the dishpan. Some kind of light coloured powder is used as a tracer of the fluid motion.

The High Atmosphere (Branch 19)

As the name implies the Branch is concerned with the very top part of the atmosphere. It works with satellite observations and also arranges for the firing of rockets and the collection of data from such firings. Ozone concentration is one particular problem which is under continuous investigation. Atmospheric chemistry is very important at high levels.

Boundary Layer Research (Branch 14)

The boundary layer is the layer from the earth's surface up to about a kilometer. It is the layer which is affected by the friction of the wind blowing over the earth's surface. It is also the layer in which the turbulent transfer of momentum, heat in sensible and latent form, from the earth's surface, particularly from the ocean, is of great importance. The boundary layer is the sink in which atmospheric kinetic energy is dissipated.

Observations are made from towers, and tethered balloons and radar and acoustic techniques are also used.

It is the aim to develop a numerical model of the boundary layer to be coupled with that of the free atmosphere.

The Meteorological Research Flight is based at the Royal Aircraft Establishment at Farnborough, in Southern England and makes flights

to collect data of various kinds. Much of the work is concerned with the instrumentation and the collection of the data on tape for computer analyses. Studies are concerned with the boundary layer transfers and with C.A.T. or clear air turbulence.

Cloud physics (Branch 15)

Cloud physics has been one of the most important branches in the office for the past 10 years. John Mason, the present Director General, was Professor of cloud physics at Imperial College in the University of London before being appointed to be D.G.M.O. in 1965, and so he has naturally shepherded this particular discipline of meteorology.

I always remember a fascinating lecture delivered by John Mason before the Royal Institution in London. These lectures are very formal and old world. One is seated in an amphitheatre with several high galleries as in a theatre so that one can look down on the speaker. Everything is quiet, like a stage before the actors come on stage. Suddenly at 6pm a clock chimes the hour. At the first stroke of six two doors open silently and the speaker slowly walks to the rostrum. At the first stroke of 7pm the speaker turns on his heels and walks out, the doors close behind him. What fantastic timing to close the last word of the final sentence at the split second of the first ping of the clock striking the hour of 7.

On the occasion of Mason's lecture he captivated the audience with actual experiments showing tiny droplets of water being squirted from hypodermic needles. The experiment was projected onto a large screen and one could see the droplets bouncing like tennis balls of the water surface in a small tank. It was a really exciting demonstration.

Cloud physics is directed at improving our knowledge of the physical processes responsible for clouds and precipitation. The scale ranges from individual dust particles of less than a micron to the organization of clouds and precipitation into bands and clusters of convective elements 10 to 100 kilometers in size. Much of the data is obtained from specially equipped aircraft while ground based radar has become established as the primary tool for observing the mesoscale rainfall structure.

One of the most important practical applications of cloud physics generally is to investigate the feasibility and true worth of rain making operations by cloud seeding. Such enterprises by commercial companies in the U.S.A. have given the technique a bad name as wild unsubstantiated claims have been made and huge profits accumulated. I will give an example.

At the end of 1967 I was in Iran as United Nations Adviser to the Director of Meteorology, who, in fact is now one of the vice-presidents of the WMO. A company arrived from America with a 2 million dollar contract to make rain and snow in the mountains by cloud seeding. Their arrival was preceded by a big publicity campaign in advance, deserts would be made to bloom etc. etc. The representatives of the company dealt directly with the Ministry of Power and avoided the meteorological service like the plague, refusing to allow meteorologists to attend the meetings with the government about the project.

Eventually, at the end of the first rainy season of a three year contract, the Iran Meteorological Department succeeded in obtaining a copy of the Company's official report to the Government. The report was marked Confidential, not to be seen by anyone outside the project operation. A study of the beautiful leather bound volume containing the so-called results of the first year of operations soon showed why the project had been so secret. The statistics had been largely cooked to claim a more than 100% success rate in rainfall increase. Storm periods during the winter during which substantial amounts of rain had fallen were classified as seeded cases and periods during which light or no rain had fallen were called unseeded cases. In some cases the seeded cases were selected when the aircraft had perhaps claimed to have seeded on the last day of a 5 day period and not flown on the days when the heavy rain fell. The whole package was wrapped up in a lot of phony statistical jargon to confuse the Iranians and make it sound all very up to date and scientific. In spite of all this nothing could be done due to political involvement of the Government and high personalities in it who could not admit they had been fooled. Further there was the usual Middle East financial spin-off.

The U.K. Met. Office has always been very cautious about cloud seeding as an operational technique claiming that more research was needed first in fundamental cloud physics.

Dynamical Climatology (Branch 20)

Dynamic climatology is a term that has been invented to make climatology sound respectable. Synoptic meteorologists used to working with daily weather maps who might find themselves posted to a climatological branch often found the subject a dead one. In 1953 in collaboration with Kenneth Hare, at that time in McGill in Montreal, formed a WMO Working Group in Dynamic Climatology. The U.K. Met. Office were less than interested at the time and it was not until about 1966, 13 years later that this branch was formed. The original Working Group died in 1956, the very year when Norman Philipps published his prize winning essay on the numerical simulation of the general circulation, and this probably signified the birth of modern dynamic climatology.

There are two kinds of models which fall within this field. Both are concerned with the general circulation as a whole. They are the time dependent models and diagnostic models. The former attempts to follow the evolution in time of the main systems. The second eliminates time and attempts to reproduce a steady state system involving the fields of motion, pressure, temperature and so forth.

Synoptic Climatology (Branch 13)

This is a less mathematical branch which relies on statistics of synoptic features to a great extent. The statistics deal with systems such as anticyclones, depressions, fronts, jet streams etc. One of the main tasks of the branch has been the operational issue of long range forecasts for a month ahead. This is based on an analogue method of trying to match the mean pressure chart for the preceding month with some chart for some other month held in the historical record series. In fact, outside verifications have shown that the forecasts are almost useless, being no better than would be expected by chance. Over some periods the forecasts are worse than persistence. However, in a vague roundabout way, the Met. Office claim they are successful. This is what they say:

> "despite unusual weather, the success rate remains about the same as in previous years, some 75% having at least moderate agreement with events as assessed "ex post facto" by an independent panel of experts. There were a few failures but also some notable successes."

The latter statement could be made by "Chiz's Choice" in the Evening News for the day's races at Victoria Park or Morphettville and is really quite meaningless, from a statistical point of view. Actually I am aware of no verifications by panels outside the Met. Office which have been favourable to the forecasts, although several have come to exactly the same conclusions, that persistence is certainly better and chance about the same as the results issued.

Forecasting Research (Branch 11)

This branch does research into short range numerical prediction models. The present model is represented by ten levels and grid points 300 kilometers apart with a grid of 100 kilometers covering an area centred on the British Isles. Experiments have been made changing the grid sizes. Further experiments have been made with models on a meso-scale, the scale that is sub-synoptic and includes such weather features as sea breezes and cumulus convection which are too small to be captured by the synoptic operational models.

One of the main problems in modeling is to input realistic initial conditions. In particular the imbalance between the wind and pressure fields generate unwanted and unsynoptic waves which may swamp the synoptic features. This balance is hard to obtain initially since the wind field is not known sufficiently accurately. In fact errors of observation are far greater than the required tolerance. Therefore much research is done into inserting slightly different initial conditions into the same basic model to see what happens, and how far different solutions diverge from one another.

Special Investigations (Branch 9)

This Branch was first set up during World War 2 to look at special problems of a military nature. For example, one of the first problems looked at was the conditions under which the exhaust from submarine snorkels could be seen and so give away the position of the submarine to Coastal Command bombers. In more recent years it has been engaged in enquiries for the aviation industry and in the fields of air pollution, storm tide surges and radio propagation, particularly along ducts at low levels where there are strong temperature inversions. Other problems have included:

The possible meteorological causes of abnormally high rates of descent on approaches to airfields, the probability that pilots in controlled air space will have to take action to avoid cumulo-nimbus clouds and an intensive study of C.A.T. (clear air turbulence) in order to determine what predictors are inherent in the 10 level model for this phenomenon.

Branch Met. Office College

It is perhaps appropriate to end with this branch as I myself was its head for some 8 years. I spent much of my time in an attempt to improve the facilities and upgrade the branch. This eventually occurred in 1972,

exactly 10 years after I had left the post and almost 20 years after I had first taken over the Branch, a change almost from the sublime to the ridiculous. The College now occupies accommodation in a large country estate formerly occupied by the Royal Air Force Training Command. Even the bar and mess white-coated waiters have been retained. During my tenancy the Training School was located in old wartime hutments at Stanmore, north of London.

The Meteorological College is responsible for the professional training of all newly recruited staff, including PhDs. Numerous courses are provided from basic observations and plotting procedures to advanced dynamical theory. Up until a few years ago there were three grades of staff.

A. Assistants with School Matriculation in a science subject.

B. Experimental Officers with the U.K. Advanced Level G.C.E. attainment. (2 passes, preferably A or B in maths and physics)

C. Scientific Officers - First or second honours in maths or physics - occasionally geography.

Today there is only one grade with numerous steps:

Assistant scientific officer
Scientific Officer
Higher scientific officer
Senior scientific officer
Principal scientific officer
Senior Principal Scientific Officer
Deputy Chief Scientific Officer
Chief Scientific Officer
Director General (Special Post)

So now a 16 year old with a school passing certificate in English and Geography can become an officer.

Courses are designed for all the above grades and also for older staff who may need revision of the latest meteorological ideas. These latter are called refresher courses.

There has always been some rivalry and indeed criticism of the role of the Met. Office in this field by the universities, who felt there should be a kind of university closed shop in the education of meteorologists. Possibly there may be problems of a similar nature in Australia today.

The leading article in the 1976 Annual Report for the Research side was on climatic variation, a topic we touched on at the last meeting of the Association. The Met. Office view has always been a cautious one, which tends to suggest that the inherent variability of the weather covers a spectrum of cycles from a few seconds to millions of years like the electromagnetic waves of the energy spectrum. The randomness of all specific frequencies will form an irregular pattern, dominated largely by chance, but with a strong built-in persistence factor. Random walks can be generated by, say, tossing a coin or tabulating red and black, or odds and evens on a roulette wheel and the length of the cycles will increase if the probability factor is increased slightly after each trial to take account of persistence.

I have touched only very briefly on the meteorology of the past 40 years, mainly as it effects the Meteorological Office. Today outside Meteorological Institutes are taking on special responsibilities. For example the United Kingdom Universities Modeling Group is located at the University of Reading and the European Medium-Range Forecasting Centre is also at Bracknell under the direction of Professor Wien Nielsen.

Today everything in fashionable meteorology is waves. The jargon is as contemporary and elitist as in any form of youth culture. The pressure gradients of the weather map have been discarded as irrelevant. We have Rossby Waves, Inertia-gravity waves, Baroclinic waves, and Kelvin waves.

The Kelvin waves interact with inertia-gravity Rossby waves to give equatorial waves with a quasi-biennial period.

We have trapped waves, tropospheric waves, stratosperic waves, and mesospheric waves.

One of the most recent waves to be studied are the ultra-long waves.

Of course we must not forget ordinary ocean waves on the beach, with which we are all perhaps more familiar.

I have always tended to be suspicious of waves. They appear to me to be a kind of optical illusion which seem to move and yet don't really, at least not unless one is a surfer on the breaking side.

However this type of outlook would be fatal to any meteorologist today.

Looking back over 40 years of meteorology the advances in both theory and technology have been almost unbelievable. One cannot but wonder what will happen in the next half century.

But that is a forecast and any attempt to make it would be Horrendous, and I will not try to undertake it.

A YEAR ON MACQUARIE ISLAND

Mr. Richard Szkup

A report of the meeting of June 1977, as recorded by R.J. Whatmough.

Macquarie Island lies about midway between Tasmania and Antarctica. On it there is an important Australian scientific base. Mr. Richard Szkup of the Bureau has just returned after 12 months' work as a meteorologist at the base, and he described his impressions of the island at the June 1977 meeting.

A term of duty at Macquarie Island begins in December and lasts for twelve months. The team of 20 travel with part of their supplies from Melbourne in the good ship "Nella Dan". This is a small vessel with a semi-circular hull designed for ice-breaking. When the seas get rough and the ship meets waves side-on, it tends to roll excessively. Rolls up to 45° either way are quite usual; the record roll is some 51°. The Danish crew seem to be used to this - they wear clogs!

At the end of the five-day trip, the first job is to unload supplies (the outgoing team from the previous year is spared this chore). In February another ship, the "Thala Dan" brings more supplies and some of these are distributed around the island by helicopter. Then the team are left to their own devices until December returns.

The island is rather barren-looking when the cloud lifts. It is about 40 km. from north to south and 5 km. from east to west. Most of it is a high plateau surrounded by steep coastal cliffs. Although water is plentiful, the main vegetation is tussock grass. At the north-east corner is a small peak joined to the rest by an isthmus on which the base has been built. Other huts, used mainly by biologists, are scattered around the coast. The island is so rugged that it is not possible to reach these huts along the coast by any animal or vehicle. The only way is to climb the plateau, walk across and climb down again - a hazardous procedure.

Weather on the island is usually cloudy. One sunny day a month is about average. In June 1976 there were only 25 hours of sunshine, and there was an 8-day stretch with none at all. Coloured sunsets are a rare event. Recorded temperatures range from a crisp $-7^{\circ}C$ to a sizzling $+10^{\circ}C$ (reached on a calm day). Usually it reaches $5\text{-}6^{\circ}$ in summer. In winter, temperatures are often below zero. The humidity is very high - usually over 90%. There is plenty of snow in winter, and even the odd fall in summer, but is always melts fairly quickly and the base has no trouble with drifts.

Auroras are common at Macquarie but they are not often visible through the cloud. The tiny particles that produce them when trapped in the earth's magnetic field are known to travel back and forth between the island and a point in Alaska.

The base is in a precarious position on its little isthmus. When a deep "low" approaches, the tide rises far enough to reduce the width of the neck by half. Among the little cluster of buildings may be found two food huts, a hut for the plumber and one for the carpenter, the cold store and the "Sealers' Inn" recreation room. A larger building houses the mess, library and pool room, and another the doctor's house and surgery. There are two sleeping huts, and a new building for the women's quarters, still under construction.

In a separate part of the base are the huts used for scientific work. For the meteorologists they include an office, a storage hut, and a balloon hut with its hydrogen-making section.

The met. team consists of four observers, one of whom is in charge of the team, and one technician. In their single-room office may be found the chart recorder for wind speed and direction, parts of the instruments for measuring direct and diffuse radiation, and the receivers for the signals from radiosondes.

They have plenty more outside. Apart from the familiar yard with its Stevenson screen, there is the radar dome and hut, where the range and direction are measured and the signal from the radiosonde is monitored. Like modern students, observers in the radar hut are having an easier time now that the pocket calculator has replacedthe slide rule.

Solar radiation is measured by an instrument placed on the top of a nearby hill. This gadget must be adjusted manually once a week according to the angle of the sun's path. A stiff climb is needed to get to it, and there are few volunteers for the job.

Balloons are launched twice a day, in the morning and evening. Their filling uses over three cylinders of hydrogen, so the gas must be made on the premises from caustic soda and a material known as "ferro-silicon". When the balloon has been inflated, the wind (average speed 20 knots) often makes the launching awkward. The trick is in getting it to rise while the end of the string is still held, and making sure that it doesn't take off into one of the base's big radio masts (a common mishap in east winds).

All the charts and graphs produced by the met. equipment are sent to Melbourne for analysis. Other reports are sent there, and also to New Zealand where they are particularly needed for forecasting.

What does the islander do in his spare time? He needs some sort of hobby - the weather is miserable, and the morale is claimed to be lower than on any other base. Some have tried skiing on the plateau. There is plenty of snow there, but conditions are not very pleasant. Some have even tried swimming, in ordinary trunks, too. Brrrrr!

The base has a dark room, and members of the team have been able to use it for their own photography, provided that they supply their own colour film. Mr. Szkup's talk would have lost something had he not indulged in that room a lot.

On their days off, meteorologists sometimes help the biologists in their work - unofficially. The island is a sanctuary, and has a varied and interesting population of animals and birds. The first wild life the visitor comes across is the Elephant Seal. These grow up to four tonnes, and the males are even heavier. They set up breeding colonies on the beaches, and wander into the base, often getting in the way of the work. Sometimes the island is visited by a few Weddel Seals from the Antarctic mainland - these are the ones that dive to great depths to catch their food. A third species, the Fur Seal, was once believed extinct, but then a colony was found here. Many years ago there was a sealers' camp on the island, and the old melting vats where they extracted blubber and oil still remain.

Whenever the sealers ran short of seals, they started on the penguins. The island has several species of these. Most numerous are the Royal Penguins. They have the world's largest penguin rookery, six hundred thousand birds, at the south end of the island, and a suburban branch with another hundred thousand near the base. They are very curious, and people can sit down in the middle of the flock without much disturbance. The main rookery is sited by a creek in a grassy valley, and there is heavy traffic along the creek to the coast. The penguins avoid collisions here by keeping to the left, in single file!

Then there are the Gentoo Penguins, the Rockhopper Penguins which really do hop over rocks rather than walk, and the King Penguins which carry their young (called "Schmoos" by expeditioners) on their legs.

Other birds keep the island beautiful. When a dead seal is washed up (they often suffer at the teeth of killer whales) the petrels move in first and get the best parts. Then come the skuas, to clean up anything left. But the birds don't have it all their own way - seals sometimes catch and eat penguins in the water.

The island has its share of vermin, too. Rabbits escaped there from wrecked ships and they are now in plague numbers. They are causing erosion in places. Mice, and some well-fed rats, are also established. They are causing problems among the wild life as well as at the base.

The attractions of Macquarie Island are many, but enough is enough. The team was very pleased when its ship came in for the next "change-over" in December, 1976.

SATELLITE METEOROLOGY

Graeme Furler

A report of the meeting of 2/8/1977.

Two hundred years ago, the first weather map was drawn to describe weather patterns. Since then, many new sources of weather data have been added to our networks of observation - islands, ships at sea, mountain tops, kites, then balloons. The artificial satellite, so useful in other kinds of measurement and communication, was an obvious next step in learning more about weather.

U.S. authorities were slow to accept that weather information from satellites would help us. They were only convinced when a big storm was photographed accidentally and the pictures gave important forecasting information.

The first test meteorological satellite, Tiros I, was launched in 1960. It was able to send T.V. cloud pictures and to sense radiation of some other wavelengths. The Tiros series was followed by the Nimbus and ATS series, in which the picture quality was improved and new kinds of picture were developed. The Gemini crews took photographs and brought back the originals - satellites have still to produce better quality than these!

In 1966 the first "production" model, in the ESSA series, was launched for the U.S. Weather Bureau. The ESSAs were a hardy race - they were planned to keep going for 3 years, but one went on for 4!

Of course, other countries haven't been able to keep out of the weather satellite game. The Russians launched one in 1967. France has plans for them, and the Japanese have just launched one of which Australia will make much use when it is in operation.

The new Japanese satellite is of the "geostationary" type. Such satellites are put into an orbit around the equator from west to east, 36,500 km. up. At this height they go round once in 24 hours, the same as a point on the earth's surface, so to us they appear to hang permanently in one spot. In theory, they could take photographs of nearly half the earth's surface, always from the same place, and transmit them to a single station on the ground.

In practice, the photographs are not clear enough around the edges, and 5 geostationary satellites are needed to cover the earth. Furthermore, the satellites tend to drift away from position, so fine adjustments must be made to the orbit from time to time. Australia has an agreement with the Japanese under which it will make these adjustments to their satellite from a control station in Canberra, in return for a share of the meteorological data.

Access to Japanese satellite data will be an important advance for satellite meteorology in Australia. The earliest data we received used to be recorded on videotape and transmitted to the U.S., where nephanalysis identified major cloud areas and fronts. The information was then sent to us, arriving two days after the pictures were recorded - much too late for forecasting.

Then came such developments as automatic picture transmission, and power from solar cells. Any country can now build a cheap tracking station and receive reasonable quality pictures. Australia has stations in Perth, Melbourne, Brisbane and Darwin, and also on the ship Nella Dan which uses the photos for weather and ice pack analysis. Adelaide's photos come through the Perth station.

Receiving satellite photos is easy for the technician. He is given predicted orbit types, and with the aid of a computer sets the antenna to track the satellite. The signal is received and punched onto paper tape. From the tape, other machines prepare positive or negative photos, taken in light or in infra-red radiation.

Our present pictures are received for several parallel orbits, one group every twelve hours. The satellite is in a polar orbit, so if it passes from north to south now, it will go from south to north in twelve hours' time. Each orbit produces photographs covering a strip 400 km. wide. The resolution is 4-7 km., so two clouds 4 km. apart will appear as one on the photo.

From the Japanese satellite, we will get photos every three hours, or in special cases (such as when tropical cyclones threaten) every hour. The cameras will allow us to zoom, enlarging an area 6-7 times if it looks interesting. Resolution will be about the same as for the present photos, but to more expensive receiving equipment, higher resolution information is available.

One hour will be the best possible time, because it will take 25 minutes to send one picture to Japan, several minutes to process it, and another 25 minutes to send it, through the satellite, to Australia.

When we examine satellite photos, we are trying to identify all the weather systems that we can and predict what they will do. In its simplest form, this means finding the clouds and asking "What will happen if this cloud moves on its present track? What happens if it hits Adelaide?" In practice we also look for factors, like jet streams, that influence the weather less directly. To take all of these things into account, we are helped by computers. However, there are still weather patterns, like Adelaide's weak summer south-easterly changes, that will remain undetectable to the most observant camera.

How do we see a jet stream? The earliest satellite photos were only television pictures - they showed only clouds by day, in a form indigestible to a computer. Now they send information about light, and radiation of other wavelengths including the infra-red, in the form of numbers that can be directly used by computers. The computers can then produce pictures for any of these wavelengths. At some wavelengths, the amount of radiation can be used to calculate the temperature of the sea surface (so far this is only experimental, but there are plans to make it a standard measurement). Other wavelengths give quite different pictures, and many quantities can be measured. At wavelengths around 6.7 microns, jet streams show up as distinct whispy marks.

From cloud patterns, we can identify highs and lows, fronts and tropical cyclones. Much time has been devoted to the study of cyclones. By comparing them with a set of photographs showing the development of six typical examples, we can classify them into six different stages of growth, ranging from T1 for "just starting" to T6 for "fully grown". From measurements of certain kinds of radiation we can tell the temperatures on the tops of the clouds around the cyclone. We can then use such theories as one that says that a cyclone moves towards the clouds that have the coldest tops!

Land and sea breezes can sometimes be detected in satellite photos. Along the Antarctic coast, dry continental air blowing offshore takes a long time to pick up moisture from the sea. By measuring the distance it goes before becoming moist, we can estimate the wind speed. While we are looking at this, we can also find out where the edge of the pack ice is.

A series of photographs taken, say, an hour apart can be built into a short movie which makes the movement of clouds quite obvious. Seen once, this movie would last only ten seconds or so, but if it is turned into an endless loop, it can be watched as often as desired and all the cloud movements around several systems can be studied. Such film loops are a great aid to satellite meteorologists, who can get from them a better understanding of what happens when, for example, a jet stream meets a cold front.

(We saw an example of a cloud motion movie, and many slides of different weather systems as they are seen by a satellite. Every little feature of a photo is an important clue - the sharp edge of the cloud behind this low, for example, tells us that there is a jet stream from the north-west in that area. On that front there, a wave low is developing, but the spotty clouds behind it are a sign of showers to follow and movement to the south-east. From the cloud pattern around a hurricane, the wind speed can be estimated. From other fine details, a computer can estimate the height above the ground at which the pressure will be, say, 500 mb. - and very accurately, too.)

How have satellite photos helped in forecasting in S.A.? On 26th June this year, a vigorous cold front passed Adelaide and a high was approaching. Would our weather clear? Satellite photos of an area at 50^{o}s showed a northerly bulge in the edge of the cloud mass, and a jet stream behind it blowing to the north-east. These features suggested that a second front would develop, so continued showers were forecast. The jet stream and "bulge" reached Mt. Gambier, and there was some very wet and windy weather with them. Another similar disturbance behind them was watched for two days, but disappeared.

A lot of our forecasts depend, as in this case, on looking for the last front in a series, and the satellites allow us to look a long way back for it.

Satellites can tell us about the temperatures at various levels in the atmosphere, and the results agree with those measured from balloons. The calculations depend, though, on information about surface pressure, and there is little of this at sea. There is a project, called GARP, in which many buoys will be launched. These buoys will transmit readings of surface pressure, surface temperature and sea temperature to the satellites. Then our information will be much better. The radiosonde will not be completely replaced - it will still be needed for cross-checking and for some of the calculations.

THE GARP EXPERIMENT

Mr. G. Vecchio

Mr. G. Vecchio gave a short talk at the June 1978 meeting on the latest developments in satellite meteorology.

The Japanese geo-stationary satellite (GMS), which has been discussed at recent meetings, was launched from Cape Canaveral on 14/7/77 but has taken many months to test. It is now "parked" over West Irian at longitude 140°E, from where it can cover an area that stretches from the Sea of Okhotsk to Antarctica, and from India to Hawaii.

The satellite is controlled from ground stations in Japan, in Thailand and near Canberra, Australia. It carries a camera to record visible light and a radiometer which scans the infra-red scene in 25 minutes by spinning and slowly tilting. Information from both is sent to Japan, where computers build up pictures, mark in the coastlines, latitudes and longitudes, and add titles which show the time of recording and whether visual or infra-red information is shown.

The pictures are then re-transmitted through the satellite to SDUS-s and MDUS-s (Small and Medium Data Utilisation Stations) in various countries. These stations can record the information and produce pictures of the whole hemisphere or enlargments of particular areas as required by regional forecasting centres.

The cycle of recording, transmitting, processing and re-transmitting takes about an hour. When there is a danger to Australia, from tropical cyclones or bushfires for example, we can request hourly pictures, but no more. The satellite can also interrogate ground stations, balloons and buoys at sea.

Adelaide's photos come from an MDUS in Melbourne. The equipment there, worth $\$\frac{1}{2}$ million, can even produce a movie film showing speeded-up cloud movements over the hemisphere. From the photos can be deduced upper atmospheric and cloud-top temperatures, sea surface temperatures (handy for forecasting fogs and tropical cyclone development) and likely frost areas on land.

The satellite soon proved its worth to the Japanese, who paid $60 million to put it up. The first published photograph showed the approach of a typhoon which later struck Japan.

The Japanese satellite is the first of a series of five to be used in the Global Atmospheric Research Program (GARP). Two more from the US are in orbit, one from Europe was launched in May, and there will be one more from the USSR. They will be spaced evenly around the equator, 3600 km above the earth's surface.

Another two satellites will follow lower polar orbits at right angles. Each will pass a given point on the ground twice a day, so one or the other will be passing that point every six hours.

With the sort of coverage these satellites will give, perhaps we will be able to predict long-term weather trends like droughts.

SOLAR SALT

Mr. C. W. Bonython

A report of the meeting of December 1976, as recorded by R. J. Whatmough

Mr. C. W. Bonython spoke at the December 1976 meeting on 'Solar Salt'. A former employee of ICI, the main Australian salt manufacturer, he was able to illustrate his talk with slides of salt workings around the world.

We see salt mainly on the kitchen table, but only about 1% of it is used there. Much more is used in preserving meat, and more than 50% is used in the chemical industry. The biggest use of all is in making PVC plastic. But still, salt is essential to our lives, as it was to the New Guinea tribe who had to smuggle it through the territory of a neighbouring enemy tribe in bamboo poles, to keep up their supply.

All salt originally came from the sea. It may be carried up in the spray to find its way into rain and rivers, or it may be deposited with the sediment of the sea to be formed into rocks, but eventually it finds its way back to the sea again.

Rock salt is formed when salt is deposited in land-locked bays and gulfs. In certain periods in the geological past, much rock salt was formed. For example, 220 million years ago there was, where Germany, England and France are now, a body of water known as the Tethys Sea. The rock salt from this sea is an important source of salt in Europe today. Rock salt is sometimes exposed at the surface, but it will not last long unless the climate is dry.

Big salt deposits also form in lakes such as Lake Eyre. The salt here has come from dried spray that was brought down by rain into the inland rivers and was left behind when the water evaporated. In Lake Eyre there are now some 400 million tonnes of salt.

One old way to mine rock salt is to wait for underground water to do it for you. Where there are salt springs at the surface, as in some parts of England, the brine can often be pumped straight out. This method has a major problem - as the water dissolves the salt away, the ground may subside, often a long way from the pumping site. In one English village, Northwich (the "wich" part is an old word for salt spring), shops have sunk until their roofs are level with the street and new ones have been built on top. To cover such damage, England has a brine-pumping tax.

Rock salt was also once mined by hand. This method was favoured in the famous mines in Siberia. Today, salt mines are worked by the same machinery that is used for coal - the salt is undercut and then blasted down. The most common mining method, however, is to bore into the salt bed, then put down a series of concentric pipes which carry hot water and compressed air down to force the salt to the surface.

Australia has very little rock salt, its only known beds having been found only recently in oil drilling. We get some of our supply by scraping from lakes, but when rock salt is lacking, the best substitute is solar salt - the evaporation of sea water or other brines.

South Australia is the main source of solar salt in this country. The ICI works at Osborne, S.A., use much of it to make soda, potash and other chemicals. In the future, solar salt from north-western Australia could be exported to Japan. Japan uses some 7 million tonnes a year at present, and is the only big industrial country without its own supply.

Seawater has many dissolved elements. The most common, in order, are chlorine, sodium, magnesium, sulphur, calcium and potassium. Further down the list can be found such oddities as gold and radium (number 39 and 40) but there is very little of these. In suitable climates, the water can be evaporated from open pans and sodium chloride - common salt - will be deposited, relatively pure at first but later mixed with other substances.

The main requirements for a solar salt industry, then, are a saline water supply, high temperatures and low rainfall for much of the year, and a shortage of competing rock salt.

Separating the different salts left by evaporation is not simple. Temperature affects the order of deposition, and the chemical engineer running a salt field must also take evaporation rate, wind and humidity into account. The water flows, or is pumped, through a series of large ponds, which must be built in an area of impervious sediments to prevent loss by seepage. The greater part of the field is a "concentrating area", where the volume of water is reduced by a factor of 10. The water passes from here to a "crystallising area" where the volume is reduced by another factor of 3 and the impure sodium chloride is deposited in a crust some 10 cm. thick. The remaining solution is pumped away.

The main impurity in the salt is gypsum. This begins to deposit some time before the salt, and five sixths of it is gone before the salt comes. The last sixth is mixed with the salt, and is removed by washing the salt and shaking it by machine. Good timing is needed when the water is let into the crystallising area - too early and there will be too much gypsum; too late and some of the sodium chloride is lost. Rain in the fields will, of course, reverse the process and reduce or delay production.

At the Dry Creek saltfields near Adelaide there are organisms in the salt which colour it slightly pink. These do no harm and help absorb solar heat. Green dye is now added to the water to help in the same way (green is not the best colour for absorption, but the Naphthol Green dye used has the best resistance to fading and no other side effects. The dye is not deposited with the salt but is drained off with the water.) At the last stages, the salt is scraped up by large dredges and formed into heaps. Grooves are dug through the crust to help drainage.

Saltfields around the world come in great variety. The means of moving the water from pond to pond varies from electric pump to windmills to just wind. In some places the salt is collected by hand raking. At Shark Bay, W.A., a new field has been built in sandy ground by laying 300 acres of polythene under the areas where salt concentration will he highest. But somewhere near every salt field is a met. station - to a salt maker, the weather is very important!

EVAPORATION

Chris Purton

A brief report of the meeting of October, 1977

Chris Purton spoke on the Bureau's new experimental evaporation forecasts for the northern Adelaide Plains.

As Adelaide grows it is swallowing up market gardening areas near the City. The gardeners have been forced to move to other areas, and many have chosen the northern Adelaide Plains around Virginia, Two Wells and Angle Vale.

In this area, most of the water is pumped from sub-artesian wells. As the number of gardens grows, the level of underground water is falling and salt water from the sea is starting to creep in. Water quotas have been imposed and meters installed to ensure that the gardeners do not destroy their water supply by over-use. So now the gardeners are trying to make the best possible use of a limited supply.

Of the water that falls onto a market garden, some evaporates, some is transpired (drawn in and used by plants and passed out through the leaf pores) and the rest soaks down into the ground. The rate of evaporation and transpiration combined, ("evapo-transpiration" for short) depends on temperature, humidity, wind speed and solar radiation. For a crop to survive, there must be enough soakage after evapo-transpiration to wash away salts that accumulate around the roots.

The rainfall on the northern Adelaide Plains is about 450 mm a year, of which two thirds falls in the months May to October. In summer, the rainfall is then not enough and irrigation is necessary.

To use the minimum possible bore water, the gardener must estimate the rainfall and evapo-transpiration and irrigate only when the calculated seepage falls short. The rainfall is easily measured but the evapo-transpiration is tricky. It can be estimated by measuring the evaporation from a standard open pan of water and multiplying by a number which depends on the type of crop. The number used allows the minimum seepage to be included in the estimate. But the right evaporating pan is hard to come by.

This is where the new service comes in. Evaporation pans are installed at Parafield and Edinburgh airfields and at Bolivar, and the Bureau combines their readings. It then reports the evaporation in the "Country Hour" on ABC radio.

It has been reported in other countries that careful control of the amount of irrigation not only saves water but improves crops, too.

WEATHER AND FOOD PRODUCTION

Alan Coleman

A brief report of the meeting of 2/8/77

For 15 years up to 1972, the United States had good harvests regularly. Russia and China had problems with food supplies and sought grain in large quantities.

Food experts advised the US Government that no variations in climate were expected and that good yields could be counted on in coming years.

Big sales were made. The large reserves that the US had built up were almost exhausted. The price of grain trebled. What went wrong?

In South Australia, the weather is governed by a succession of highs and lows from the west. The strengths of these highs and lows vary according to season - in a typical winter, lows move well north and highs are short-lived, so there is plenty of rain; in summer, the fronts are weak and the highs are large, so there is much less rain.

These typical seasonal patterns don't happen every year, however. The lows can move further north in some years, south in others. This year (1977) lows have steered away from Adelaide or have picked up less moisture in the Bight.

Crops are affected more by some weather factors than by others. A single severe storm can wipe out a crop. If there is no trouble with severe storms, the number of storms that bring rain is most important. Those parts of our weather that have the greatest effects we call "crop weather". The changes in the courses of lows near South Australia, while small in distance, can have a large effect on our crop weather.

If South Australia's crops do poorly this year, there will still be plenty of food in Australia as a whole. In parts of South-East Asia, though, some crop areas are so concentrated that local weather fluctuations can have drastic results.

Back in the US in 1972, the experts were saying that all the weather fluctuations would average out producing no effect. This has been true for fifteen years, but those fifteen years were anomalous. The Government agreed to sell the grain.

In 1973, the harvest was fair. In 1974, it was disastrous. 1975 and 1976 also brought bad seasons, and now the US is short of grain. So what do the advisers say now? *"This is normal, keep going!"* What better illustration of the sensitivity of crops to the weather?

WIND ENERGY

J. O. M. Bockris

A summary of the address at the October meeting,
as recorded by R. J. Whatmough.

Our main speaker at the October meeting was Professor John Bockris, of the Institute of Solar and Electromechanical Energy Conversion at Flinders University. He discussed the costs and problems of using the wind as an energy source and looked at the fate of our other sources.

One of his papers on the subject was used as a source of illustrations.

The world's present energy supplies are running down. In Australia, we have enough coal and uranium for a long time yet, but we also depend on oil and our own sources of that mineral will last only another five years or so. It has been estimated that by the year 2000, there will be so little oil and its price will be so high that it won't be worth the cost of using it.

We could go back to coal for many purposes, but by the year 2050, we will have to give that up, partly because of the pollution caused by its extensive use.

In 1950, we said *"Our oil will run out, but we will soon have atomic energy"*. Now we know that it is not that simple. If we use uranium as a simple source of heat, it will be exhausted as rapidly as oil. We could get more heat from it by "breeding" - converting it to plutonium first - but this process has not been made efficient enough. Much more energy could be obtained from the fusion of hydrogen, but we do not know how to control a fusion reaction, and by the time we manage it, oil may already have run out.

The only remaining source of energy is the sun, either in its radiation or in its effect on the ocean or atmosphere. There are four major possibilities.

The sun's rays could drive a bank of photovoltaic couples, producing electricity directly. Such methods were once out of the question - now they are just too expensive.

The sun's rays can, with the aid of reflectors, produce heat, the heat being used to make other forms of energy. This method has possibilities - there are plans for power plants to use it not far in the future.

It seems possible, in theory, to build engines that are driven by the temperature differences in the oceans. But now there appear to be problems with this method, too, and they are not well understood.

The fourth possibility is energy from the wind. Wind was put to use in the 12th and 13th century when windmills were built in Europe to grind corn. Between 1900 and 1940, inventors and companies dabbled with larger wind machines.

One outstanding effort was a 42-foot rotor in the USA, called "Grandfather's Nob". It drove a generator and produced 1000 kw in a 30 mph wind. Unfortunately, it tried to keep going during a storm and shook itself to

pieces. We know better now. Any future rotor will have to feather itself in high winds. Other wind-driven generators were tried in Britain and Russia.

With the coming of cheap Middle East oil in the 1930s, people soon lost interest in wind. Since 1970, they have suddenly become interested again... Putnam's "Wind Energy" and Golding's "Electricity from the Wind" are examples of fairly recent literature on the subject.

We can estimate the energy that can be extracted from the wind by a rotor. The energy of motion of a given volume of air is proportional to the square of the wind speed (that is, double the wind speed, four times the energy). The power brought by the wind to a rotor is proportional to the cube of the wind speed (double the speed, eight times the energy) and to the square of the length of the rotor arms. A very complicated piece of aerodynamic theory proves that the rotor can pick up about two thirds of this power - the exact shape of the rotor doesn't matter very much.

In choosing the site for a rotor, we are interested in the average wind power over a long period, so we need to know the average of the cube of the wind's speed. If the speed were always the same, we could install a recording anemometer (which averages the speed over an hour or so) and take the cube of the average. But in practice, the speed is sometimes higher and sometimes lower than average, and power increases so rapidly with speed that high speeds increase the power more than low speeds reduce it. So we need a better kind of anemometer to tell us about the short gusts too, because they will give us most of the energy.

Furthermore, in taking the average, we need to ignore speeds less than about 15 km/h (they will not be enough to overcome drag in the rotor and generator) and greater than about 60 km/h (when the rotor is feathered for storm protection). If only an average speed is known, we can estimate average power but only roughly.

The useful sites will be those with winds greater than say 20 km/h much of the time. These will be windy places such as parts of the South Australian coast.

Such places will have transmission problems. Most of the electricity will be required in Sydney and Melbourne, but wires leading that far are expensive. It would be cheap, however, to use the electricity to produce hydrogen and pipe that as a fuel.

Calculations are now possible. We can assume rotors up to 100 metres radius and estimate the efficiencies of generating electricity (90%), producing hydrogen (75%) and turning it back to electricity (65-70%). In a few years we can assume that each person will consume 5 kw of electricity. Then he can supply everyone in SA from a 30 km/h wind using 2000 windmills! At sea, where wind speeds are about double those on land, the windmills would be spread over a 50 km square, allowing enough space between them so that they don't block one another's wind supplies.

Of course, a 100 metre rotor is not easy to build. You can't suspend it from its axle like an ordinary wheel. A better idea is to support it by its rim on a moving base. There are other more elaborate schemes, like large banks of small rotors. They are all about as efficient as the single rotor, but their costs and engineering problems vary.

The hydrogen produced can be stored under pressure. This storage can then act as a reservoir for calm periods.

One unfortunate by-product when hydrogen is produced from seawater is chlorine. We cannot afford to let this escape into the atmosphere. At an extra cost, we can convert it to hydrochloric acid which can be let out into the water with a minimum of damage.

The cost of installing wind power in SA now, including windmills, generators, hydrogen production and storage and fuel cells to produce hydrogen in cities would be $500 to $1000 a kilowatt. That will be about $4000 a person, or $4000 million for the whole state. It will be expensive, but will save a lot of costly research that other energy sources require.

In the question period that followed Professor Bockris' talk we learned that to produce a million BTU-s of energy from petrol (at the refinery gate) we would pay $2.75. To produce it from the wind by rotors and hydrogen we would pay about $3.50. So wind power is not quite the cheapest way yet.

The costs for rotors at sea do not include routine maintenance like scraping off the barnacles.

Hydrogen can be conveniently stored under pressure in an iron-titanium alloy. One ton of the charged alloy would take a car for 300 miles with suitably adjusted ignition.

Jet streams are very energetic but beyond our technology to exploit at present.

Tidal power has been used in France, but the tides aren't big enough in most places.

RECENT DROUGHT IN THE SAHEL

Dr. P. Lamb

A report of the meeting of 6/10/77 as recorded by R. J. Whatmough

The drought in the Sahel (the Sub-Saharan region of West Africa) started in 1968, and may still be in progress. It has been well documented in newspapers, magazines and TV documentaries.

There have been big fluctuations of climate in this area before, but the drought has caught the interest of those meteorologists who study long-term climate changes. Because drought has bad effects, they are encouraged by the knowledge that their study will be useful.

The drought is considered to be the result of large-scale anomalies in the circulation of the atmosphere. To understand its causes, we will first consider what produces the rain locally, and then how the large-scale changes affect the process.

The Sahel lies inland from the north coast of the Gulf of Guinea, between the latitudes 10°N and 20°N. It is a transition savannah zone between wet coastal areas and dry desert areas. The Senegal and Niger Rivers are the main streams draining the area, which is some 1000 km wide and 4000 km long.

Since 1945, rainfall records have been kept at 20 places in the region. Older records are scarce, there being only 4 or 5 stations in 1940. Average monthly rainfall figures show that 80% of the year's rain falls in the northern summer, between July and September. This "Sub-Saharan rainy season" is short and unreliable - if it is missed, there will be little rain until the following year. In the last 10 years, 7 seasons have been missed.

An index value, derived from the rainfall in the Sahel region for each year from 1940 to 1975 shows some bad years between 1940 and 1950, good years from 1950 to 1960, and a string of bad years since 1968. River level records suggest that 1913, and several years between 1920 and 1930, were also bad.

Normal yearly rainfall varies greatly within the region, decreasing rapidly from south to north and more slowly from west to east. It ranges from 2000 to 800 mm at 12°N and from 200 to 100 mm at 18°N.

In the rainy season, two major wind systems meet in the Sahel. The North East Trades bring hot, very dry air south-westwards across the Sahara. The South East Trades bring very moist and somewhat cooler air across the South Atlantic Ocean and the Gulf of Guinea. This air moves north-westwards until it reaches the equator, then turns north-eastwards to meet the northern air head-on in a major stationary front known as the Inter-Tropical Front.

The Inter-Tropical Front contacts the ground along an east-west line at about 20°N, on the northern edge of the Sahel. To the south, the hot air is present, at increasing heights, as far as 15°N. Four major weather zones can be distinguished near the front.

North of the front, where the cooler air does not reach, there is no cloud development, and no rain. Immediately south of the front, where there is a limited depth of moist air, cumulus forms in the afternoons, but it does not fully develop because the rising air meets the hot air above the frontal surface. Further south, the thicker moist layer allows full development of

cumulus. Finally, south of about 10°N, stratiform clouds are present and dominate the weather.

It is the zone of full cumulus growth that is most interesting. The cumulus cells can grow up to the middle troposphere where they meet a strong easterly wind which causes them to move westwards. They tend to form in north-south bands of perhaps 100 cells, hundreds of kilometres long and about 100 km apart. The bands, known as "West African Disturbance Lines", move out over the Atlantic Ocean, where some decay and some persist as far as the Carribean and south-eastern USA!

Geosynchronous satellites can photograph the disturbance lines at half-hour intervals, so something of their history is known. Some come in from the Sudan on the other side of Africa, but most appear in the afternoons over elevated ground. Elevated areas are likely sites for cumulus formation, because the air directly above them is closer to the ground than air at the same height elsewhere and is therefore heated more strongly than surrounding air.

What is happening on a larger scale? During the rainy season, there are two major jet streams in or near northern Africa, both in the upper troposphere.

The Tropical Easterly Jet blows westwards at 12,000 m near 15°N. It begins near the Phillipines and persists across Africa. It is only present in the northern summer, and it is the earth's only easterly jet stream.

The Subtropical Westerly Jet blows eastwards at 9,000-10,000 m, near 35°N. It crosses southern Europe and fluctuates considerably about its average direction.

Between these two jets there is an area of subsidence (an upper-level "high") which inhibits the growth of thunderstorms. The presence of this feature is another reason why there is little rain in the Sahara.

There are more westerly jet streams about the north polar areas, known together as the Circum-Polar Vortex. One theory of the cause of the Sub-Saharan drought, known as the "Equatorial Expansion Hypothesis", runs as follows. The temperature in the Northern Hemisphere outside the tropics is lower than normal. There is more air at the pole, so the Circum-Polar Vortex has expanded. The Subtropical Westerly and Tropical Easterly Jets, and the upper high between them, have been displaced 4-5° southwards, so the subsidence is affecting thunderstorms in the Sahel.

There is not much data to support this argument and many meteorologists disagree with it. Furthermore, the expansion of the vortex occurs mainly in the northern winter - not in the Sub-Saharan wet season.

Along longitude 32°E, which runs from Durban, South Africa to Egypt, there are many stations that make upper atmospheric measurements. Contour plots showing the east-west flow across this line, at latitudes 8-46°N and at heights 5,000-13,000 m, have been drawn for August 1968 when there was a drought, and for August 1967 when there was none, and compared. They show that the Subtropical Westerly Jet moved distinctly south in the drought year, and that the Tropical Easterly Jet moved slightly south at the same time.

Unfortunately, the apparent pattern is not consistent. The same southward movement has often happened in August in non-drought years, and plots for July do not show the same changes.

A lot of relevant information comes from ships in the Atlantic Ocean. Figures for wind speed, surface pressure, surface temperature, precipitation and amount of cloud can be extracted for drought years and compared with long term averages.

Wind speeds in 1968 were lower than average in a belt running roughly east-west across the Atlantic and meeting the African coast opposite the Sahel. Average speeds for five drought years taken together show the same pattern but not so strongly. We may conclude that the South East Trades did not get so far north in drought years.

Pressure readings taken on ships are not very reliable, but average pressures for a parallel of latitude right across the Atlantic can be calculated. Relative to 60-year averages, they show a pressure trough at 1-2°S latitude in 1968. This trough would be consistent with weaker onshore (or stronger offshore) winds in the Sahel.

In 1968, sea surface temperatures for the months July to September were up to $\frac{1}{2}$° cooler than the average for these months north of the Sahel latitudes, and up to $\frac{1}{2}$° warmer to the south. The figures show that the zone of maximum temperature shifted 200-300 km to the south.

Finally, precipitation frequency figures show that in 1968, the rain and cloud were further south than average in the central Atlantic, and more abundant off the Guinea coast. Together, all these measurements show that there was a general shift of weather features over the Atlantic Ocean to the south in 1968.

Some supporters of the Circum-Polar Vortex expansion theories have made gloomy predictions that there will be no more good rains in the Sahel for the rest of the century. Others have written that there is no proven trend in the data, and that the drought is part of the normal climate and not a change of climate, but the "doomsday predictions" are reaching the newspapers more often.

People came to the Australian Bureau of Meteorology asking for comments on such climatic changes. The Bureau has told them that there is no evidence for changes, and a government report on the subject was published. Much more work is being done in this area and more definitive statements are likely soon.

A similar report has been published in New Zealand. In the USA, a bill has been passed in Congress to finance more research into a climatic change and its effects. Researchers will make more temperature and precipitation measurements, develop new computer models, and build systems to monitor various atmospheric quantities including the concentration of substances present in traces at the upper levels.

Dr. Lamb added the following remarks in answer to questions.

The sea surface temperatures measured in the 1968 wet season were not greatly different from average values. (Statistically speaking, such temperatures vary randomly from one "normal" year to another. In ten normal years, there would be six in which the temperature would fluctuate further from the average than it did in 1968. In three of these it would vary the same way but more so, and in three, further the opposite way.)

It is not known whether the weather systems in the Southern Hemisphere also moved south in 1968. There is a lack of data from the southern African areas because so many have had revolutions lately!

The sea temperature patterns are interesting. The temperatures are affected by wind over the surface. Any anomalies seem to affect the weather on a seasonal scale.

The Bureau has been studying the shift of southern weather patterns over a recent five-year period, by tracing the development and decay of lows over the whole hemisphere.

Some of the major drought years in Australia do seem to correlate with the droughts in the Sahel. There have been several such odd correlations between weather patterns in distant parts of the world.

Cooler temperatures in parts of the Northern Hemisphere, and an increase of ice in Canada, do seem to support the theory that climatic fluctuations are caused by cold air swirling out of the Arctic region. But some say that the increased air pollution over North America is reflecting more sunlight away from the earth. The increase in dust is apparently more important than the increase in carbon dioxide, which would on its own raise the temperature considerably.

WEATHER AND BOATING

A report of the meeting of April 1978, as recorded by *R. J. Whatmough*

1. A layman's view

Mr. Bruce Harris, the "News" fishing and boating writer, began the discussion on this subject at the April 1978 meeting by stating his qualifications - he has lived for many years near the sea, and he has been caught out in bad weather.

According to Lloyd's Register, the coastline from Outer Harbour to Cape Jervis is the second most dangerous in the world. The first is in the Bay of Biscay - these are the only two places with "dodge" tides, and they have similar weather.

On a summer afternoon, the south-westerly sea breezes on our coast don't start until the tide turns in. Then seas build up, first into long swells, then short chops, and boats get into trouble. If heavy swells are breaking over the bar at Glenelg, the risk will be greatest close to home. Many boats have been caught here.

The south-westerly is our worst wind for an amateur "boatie". The other two all-weather ramps, at Outer Harbour and North Haven, are also tricky in such winds, particularly at the Harbour when the tide is going out. Mr. Harris's advice to the man with a boat at Outer Harbour is "If there is any white-cap in sight, don't go out."

There are many clues to the weather that boat people can use. Sea birds can forecast the next day's wind - gulls flying high are riding with a south wind, while those flying low are avoiding a north wind.

Whiting have been biting at Glenelg for at least six weeks. Normally they are only arriving now, though they were early last year too. They don't start biting until the temperature falls below about 51°F in deep water - the temperature is now low (April 1978). Does this mean that we are to have another dry, cold winter? Why aren't the scientists looking into this? Perhaps they could also tell us how whiting come back to the same place each year, or why snapper always arrive at Port Lincoln on 1st February each year (and leave after 2nd February as some claim).

Just before a change, snook rise and bite energetically - do they sense pressure changes?

The moon has big effects on the sea. A full moon produces extremes - either cloud disperses, or there is a big storm.

The "red sky at night" saying is true. It is only superstition of course, but fishermen use it.

Some 150-200 thousand people regularly use boats. Most would not know how to handle them in heavy seas. The Bureau could help these people by refraining from such terms as "moderate seas", which is applied to a sea state quite hazardous for small boats. There is a need for a special forecast for weekend boaters, for they are more important in terms of numbers and risk to life than the users of big boats at Outer Harbour.

It would also help to have a standard weather man in use by all our TV stations. At present, they all show different maps and sometimes fronts appear in different places. Their artists have intervened somewhere.

We know that when there is a big swell there is a storm to the south. We tell people such things in the papers, but a TV report would have a greater impact.

People tend to ignore the forecasts, because forecasts are "always wrong". Perhaps the Bureau could contact the lockmaster at Glenelg and the Signal Tower at Outer Harbour to check water conditions there, and broadcast this information with the forecasts. People would have to believe an on-the-spot report.

2. A meteorologist's view

Mr. Len Broadbridge of the Bureau added a meteorologist's views to the discussion. He observed that some of the Bureau's forecasts have been inaccurate, but then he has sometimes gone fishing on one of Mr. Harris's reports and caught nothing!

TV weather maps vary greatly, and interesting things have indeed happened to weather reports. Channels 9 and 10 send their girls to the Bureau for briefing. Only Channels 2 and 10 show isobars on their maps.

The idea of local reports of sea conditions is nice. The Bureau once stopped radio coastal weather forecasts to cut costs, but restored them after a big fuss in parliament.

Wind and sea predictions are the hardest routine forecasting task, and it is in this area that we get most criticism. South Australia has over 3000 km of coast, and forecasts, issued for the Far West, are for average conditions over large areas. More local features such as the gulfs and Kangaroo Island make conditions variable and boat users need to know about local influences.

Streaky Bay on the West Coast is an interesting case; it faces north, so there is a local problem with north winds.

Off Yorke Peninsula, the tide from St. Vincent Gulf runs out from east to west in the morning and returns in the afternoon. South-east winds are re-inforced in the morning and reduced in the afternoon by the tides, so the windy period is the morning, not the afternoon as in Adelaide. The Adelaide pattern, rising south-westerlies in the afternoon with incoming tide, confirms amateur observations.

Sea breezes are strongest not on the hottest days, but on moderate days. These are usually the south-east wind days in summer. It used to be standard Bureau practice, on hot north-east wind days when no low was approaching, to forecast a light morning breeze with a stronger sea breeze in the afternoon. On such days, though, the sea breeze is usually very weak, and future forecasts will probably say 'Winds becoming light and variable in the afternoon."

There are some problem areas for forecasting winds at sea. If there is a south-east or north-west wind in Backstairs Passage of, say, 10-15 knots, it will be 10 knots stronger near Cape Jervis. Off Port Stanvac on summer evenings, when the sea breeze drops, there can be strong gully winds - people who rely on "metropolitan waters" forecasts here may be carried out to sea unexpectedly.

It is important to remember that forecast wind speeds are averages only - not maxima. Wind speed cannot always be predicted from pressure gradients either - there may be big fluctuations of wind in a steady pressure pattern.

The Bureau issues forecasts, to radio stations, shipping radio and fishermen, at 5.30 and 11.30 am, and at 5.00 and 10.15 pm. Telephone enquiries are common - it receives over 130 a day, and half of these are for waters forecasts. The staff are happy to forecast for one day ahead, but no further - the sea is sensitive to small changes in weather patterns. That is why people are advised to check with the Bureau again for later forecasts.

It is difficult to decide when to issue a Strong Wind warning. Professional fishermen want to know when winds stronger than 30 knots are expected. For small boats, 25 knots is a more useful starting point (20 knots might be even better, but 25 is usual around the world.) 8-foot waves with 25 knot winds are too big to be considered "moderate" for small boats. Remember, too, that waves always come in a mixture of sizes, and there are "freak" waves for boats as well as for rock fishermen.

Sometimes weather patterns change so quickly that it is not clear whether there will be a danger or not. In such cases it is safer to issue a warning than to try to avoid a false alarm. This policy won't always work indefinitely, though. Sometimes, after a long chain of warnings and no action, the Bureau weakens a bit and withdraws the warnings - then, in comes the front.....

The new Japanese weather satellite has just been installed over West Irian. Now the Bureau can tell where the fronts are, and their short term front forecasts will be much better. Recently the remains of a tropical cyclone passed Perth and headed south-east. Satellite photos showed that its decay was continuing, so a weak change could be safely forecast.

Some of the other fronts in the Bight are fast. Some of them have "waves" which cause parts of a front to move "backwards", contrary to all predictions. Kangaroo Island fishermen say that fronts always arrive between 3 and 6 am, and often they complain that the front arrived before it was forecast. The Bureau can now catch some of these fronts before they strike, but they need more observers and money.

Mr. Broadbridge's advice to people in boats is - "If the sky darkens rapidly, get out". He knows that thunderstorms can cause brief havoc.

3. Discussion

Is a "slight" sea the limit for a twelve-foot open boat?

Yes. There will be waves up to four feet high.

What wind strength is 'moderate'?

International definitions apply to the open sea. Near the coast, waves change, becoming smaller and closer (close waves are a special problem). The Bureau has studied the problem for the Adelaide coast. Using observations 2 km off Glenelg, it has produced a guide relating sea state to wind strengths for different wind directions. There may be a big difference between the sea states at Glenelg and Outer Harbour on the same day.

How much effect do tides have on wind strength?

The tide has as strong an effect as the pressure gradient or the time of day. Afternoon sea breezes are weaker when there are dodge tides, stronger when there are spring tides. In winter, sea breezes come from the north-west and are strongest when the tide is going out.

Doesn't the sea breeze only go half a mile inland?

It is strongest in that range but still present further in.

Which way do the tides flow in the gulfs?

The outgoing tide in St. Vincent Gulf runs south to Sellicks Beach, then west. The incoming tide rises along the centre of the Gulf first, then spreads to the sides. The sand drift is away from Moana in both directions. The total movement of water is only about 6 km each way. Man has added much fresh water to the Gulf, and the tides cannot remove it. That is why there are no baracoota or blue tuna any more - there are too many chemicals.

Why do we have dodge tides? Why do they only occur in two places?

Dodge tides occur here when the moon is in the first or third quarter, and the effects of the sun and moon oppose each other to cause weaker tides everywhere. There are only two narrow entrances from the sea around Kangaroo Island, and these do not let the flow in or out at these times.